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2585
Operating Temperatures
for a Convectively Cooled
Recessed Incandescent
Light Fixture

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MASTER

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FOR
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OPERATING TEMPERATURES FOR A CONVECTIVELY COOLED
RECESSED INCANDESCENT LIGHT FIXTURE

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FOREWORD

This is one of a series of reports to be published describing research, development, and demonstration activities in support of the National Program for Building Thermal Envelope Systems and Insulating Materials. The National Program involves several federal agencies and many other organizations in the public and private sectors who are addressing the national objective of decreasing energy wastes in the heating and cooling of buildings. Results described in this report are part of the National Program through delegation of management responsibilities for the DOE lead role to the Oak Ridge National Laboratory.

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SUMMARY

Test results are given in this report for the operation of a recessed incandescent light fixture intended for residential use. The fixture which has been designed and marketed by Thomas Industries, Inc. is labeled for use in direct contact with attic thermal insulation. Temperature control of the powered fixture is provided by convective heat transfer from the ceiling side of the fixture.

The fixture was operated at power levels up to two times the rated power of 75 watts and under thermal insulations up to R-40. In all operating configurations tested the fixture surface in contact with attic insulation was found to be less than 175°C. The observed surface temperatures are judged to be safe for operation in contact with loose-fill or batt-type insulations.

It was observed that the power leads inside one fixture configuration are exposed to temperatures as high as 163°C. The electrical insulation could, therefore, have a limited life. The properties of the internal fixture wiring were not, however, studied in detail.

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Operating Temperatures for a Convectively Cooled Recessed Incandescent Light Fixture

Introduction

A previous study⁽¹⁾ of recessed light fixtures showed that operation of fixtures covered by thermal insulation resulted in temperatures in excess of 200°C. Combinations of insulation-covered recessed fixtures and combustible insulation were, consequently, identified as a potential fire hazard. The suggestion was also made that the operating temperatures of the tested fixtures could be lowered by promoting heat transfer away from the fixture by convection-conduction to the air on the ceiling side.

A recessed fixture has been marketed with a label declaring that it can be operated in direct contact with attic thermal insulation. The fixture is open to the air on the ceiling side to provide cooling. A sample of the new fixture was obtained through normal distribution channels, instrumented, and operated at three power levels to determine maximum steady state operating temperatures under attic thermal insulation.

Experimental apparatus and procedure

The experimental procedure used in this work was similar to that described in a previous report on the test facility.⁽¹⁾ The fixture to be tested was mounted in a 24 X 48-inch box that is 9 inches deep with ½-inch sheet rock used to simulate a ceiling. Copper-constantan thermocouples were mechanically

(1) "Recessed Light Fixture Test Facility", D. W. Yarbrough, K. T. Yoo, and P. B. Koneru, ORNL/SUB-7504/3, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830

fixed to the attic side surface of the fixture. This was done by drilling small holes in the body of the fixture and attaching the thermocouples to the fixture with sheet metal screws. One thermocouple was attached to the ceiling side trim in a similar manner. The thermal EMF's produced by the several thermocouples were measured relative to an ice bath using a digital multimeter⁽²⁾ and converted to temperatures using thermocouple reference tables.⁽³⁾ Temperature determination is judged to be accurate to within $\pm 1^{\circ}\text{C}$.⁽⁴⁾ Figure 1 shows the positioning of the fixture within the test section and the location of the thermocouples on the fixture. Figures 2 through 4 are photographs of the instrumented fixture and trims that were studied.

The fixture was thermally insulated on the attic side with ten inches of loose-fill rock wool insulation installed at a density of approximately 2.6 lbs/ft³. The depth of loose-fill insulation directly above the fixture was 3.5 inches. In addition to the loose-fill insulation, R-13 fiberglass batts were placed on top of the loose fill in order to determine operating temperature increase due to increased attic side thermal insulation. Fixture operating temperatures were recorded for attic side insulations approaching R-40.

(2) Hewlett Packard 3405A Digital Voltmeter with stated accuracy $\pm(2\mu\text{V} + 0.03\% \text{ of reading})$.

(3) "Thermocouple Reference Tables Based on the IPTS-68", Robert L. Powell et al., N.B.S. Monograph 125.

(4) Thermocouples were checked against the ice point and steam point. The error at the ice point was estimated to be less than 0.1°C . The error at the steam point was estimated to be less than 0.3°C .

Thermocouple Locations

- (1) Top of Fixture
- (2), (3) Side of Fixture, $2\frac{1}{2}$ inches above Base Plate
- (4) Ceiling Side Trim (see Figs. 3 and 4)
- (5), (6) Electrical Connector Box

Figure 1. Top View of Recessed Fixture Test Section

Figure 2. Photograph of the Instrumented Fixture.

Figure 3. Fixture Trim R-232-W with Thermocouple Attached.

Figure 4. Fixture Trim R-230-W with Thermocouple Attached.

The fixture that was tested is identified by the manufacturer, Thomas Industries, Inc.⁽⁵⁾, as model number R1-1C. It is rated at 75 watts by the producer and can be installed with any one of six ceiling side trims. The present series of tests were completed with two typical trims. The first was model number R-232-W (Figure 3) which is a flat ring of metal that is installed flush with the ceiling. Trim R-232-W has a ceiling side open space approximately four inches in diameter. The second trim used, R-230-W (Figure 4), has the appearance of a spotlight which directs light away from the vertical. It also has an open space approximately four inches in diameter.

The fixture was operated with 75, 100, 150, and 200 watt bulbs installed. The 200 watt bulbs were found to protrude from the fixture and were judged, therefore, to represent an unrealistic configuration. Both the ceiling side and the attic side of the test section were in contact with room air at 20-24°C. In each case the fixture was operated for a continuous period long enough to establish steady state.

Ceiling side trim temperatures were measured by a mechanically attached thermocouple. The trim temperature is of interest since it affects surrounding painted surfaces.

Discussion of results

Table 1 shows the steady state temperatures that were observed for the attic side fixture surface and the ceiling side trim. Duplicate entries for a given configuration show the changes resulting from removal and replacement of the thermal insulation. Power variations and ambient temperature variations also affect the steady state operating temperatures. The maximum observed temperatures were on the box containing the electrical connec-

(5) Thomas Industries, Inc., Residential Lighting Division
207 East Broad, Louisville, KY 40232

tion of the fixture to the power supply. Thermocouples were exchanged and circuit resistances were checked to verify the observed temperatures. The connector box is attached to the fixture body by a metal plate. The connecting plate is covered by the maximum insulation depth. The present results indicate that the maximum observed temperatures on the fixture surface result from heat conduction along the base plate.

The results in Table 1 show steady state temperatures in the range 90°C to 123°C for operation at 75 watts under thermal insulation. The maximum surface temperature observed was 171°C which resulted from operation of the insulated fixture with trim R-232-W and a 150 watt bulb. The observed surface temperatures are judged to be safe for operation with loose-fill fiberglass, rock wool or cellulose insulation or insulating batts.

The electrical connection of the lamp socket to the power supply using trim R-230-W is such that the wiring is exposed to direct heating from the incandescent lamp. A thermocouple was attached to one of the wires to determine the exposure temperature of the electrical insulation. Temperatures as high as 127°C were observed when the insulated fixture was operated at 75 watts and 164°C when the fixture was operated at 100 watts. It was also noted that the electrical wiring in the connector box is exposed to relatively high temperatures when the fixture is thermally insulated. Examination of the wiring in the connector box revealed discoloration of the electrical insulation believed due to operation at high temperature. The box carries a statement that 60°C rated wire should be used. The insulated fixture, however, operates well above 60°C . The temperature environment of the electrical insulation could result in rapid deterioration of the insulation which will affect the useful life of the fixture. A detailed analysis of the characteristics of the electrical insulation was not undertaken but should be considered by the manufacturer.

Table 1

Steady State Operating Temperatures for the
Thomas R1-1C Recessed Light Fixture

Thermal Insulation (Estimated R-value)	Bulb size (watts)	Observed temperatures (°C)						Maximum Observed Temperature (°C)
		Location (a)						
		(1)	(2)	(3)	(4)	(5)	(6)	
Trim Number R-232-W(b)								
27	75	107	107	107		118		118
27	75	110	110	110		120		120
27	75	107	107	106	107	118		118
40	75	111	111	111	112	123		123
40	100	134	134	134	133	146		146
27	150	156	156	156		167		167
40	150	161	161	161	158	171		171
40	200	150	150	150	148	161		161
Trim Number R-230-W								
0	75	39	38	37	37	44	44	44
40	75	96	97	96	103	107		107
40	75	81		81	88	91	91	91
40	75	81		81	87	90	90	90
40	75	86	87	86	92	96	96	96
40	75	94	95	94	97	114	114	114
40	100	118	119	118	125	129		129
40	100	104		103	111	113	114	114
40	100	99		99	107	110	110	110
40	150	136	136	136	143	147		147
40	150	122	123	122	128	133	133	133
40	150	120	120	120	126	131	131	131
40	150	126	126	125	131	137	137	137
40	150	132	133	132	134	142	142	142

a) Thermocouple Locations are shown in Figure 1

b) Thomas Industries, Inc. Part Number

Figure 5. Maximum Observed Temperatures for Thomas R1-1C Recessed Light Fixture

A graphical presentation of the temperature data is given in Figure 5. The range of operating temperatures for previously tested thermally insulated recessed fixtures ⁽¹⁾ is shown in the figure for comparison.

Conclusions

- The Thomas Industries, Inc. R1-1C recessed fixture operated at temperatures below 175°C for all configurations tested. The fixture was operated at 150 watts and under thermal insulations up to R-40.
- The fixture when operated at rated power is safe from hazards associated with the surface temperature of the fixture.
- The internal wiring associated with trims of the type represented by R-232-W should be redesigned to prevent deterioration of the electrical insulation with time.
- Rapid deterioration of the electrical insulation on the wiring in the connector box might result from operation of the fixture under thermal insulation.

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